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Materiel Test Procedure 10-1-003
Yuma Proving Ground

U. S. ARMY TEST AND EVALUATION COMMAND
BACKGROUND DOCUMENT

DESERT TERRAIN

1. INTRODUCTION

One of the critical factors in testing is the geophysical environment. This is true regardless of climate or location. These factors exist world-wide, but nowhere does their severity and range of extremes surpass that found in the deserts of the world.

The lack of precipitation has a multiple effect on the terrain of the desert. The surfaces of parent rock are steep and rough, free from attack by frequent rains or the questing roots of vegetation. Material which is broken away mechanically is deposited in deep layers, often unconsolidated except by its own weight. Scanty vegetation fails to reduce winds, or retain surface layers. The resulting sand and dust storms are highly destructive to materiel. They are also the cause of vast sand sheets and massive dunes, major influences on desert warfare.

All materiel transported across land will see surface roughness and bearing strength translated into shock and vibration by the carrier. The stability of stacked boxes and containers will partly depend on the bearing pressure of the materiel on which they are placed. Shelters, towers, and masts will sense the resistance of the surface and sub-surface through their anchoring systems. The security of uncamouflaged items during both storage and operation will depend on their degree of contrast with the terrain background.

These characteristics vary between deserts, since there are several types of deserts, in different latitudes and at different elevations. To plan a desert environmental test, it is necessary to consider not only desert terrain, but also the characteristics of the various types.

2. DEFINITION OF A DESERT

A desert is generally defined as a region with an arid climate, in which the potential evaporation rate exceeds the precipitation rate. The arid climate results in the scanty vegetation which is characteristic of such a climate (xerophytic or drought resistant). The lack of vegetation cover, in turn, results in soils with a low organic content, and contributes directly to the distinctive shaping of the topography.

Deserts can be classified in many different ways. Most of the classification systems are based on either climatic, terrain, or vegetation factors. The boundaries of the desert are defined as "core" or "transition" areas. The core area representing that part of the desert which exhibits all the characteristics of a desert environment, and the transition area that part of a desert that exhibits some characteristics of desert environment but cannot be clearly defined as a desert.

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Regardless of the definition desert areas account for more than 15 percent of the world's land surface. These areas are illustrated in Army Regulation 70-38 Map of Climatic Categories.

3. DESERT TERRAIN CLASSIFICATION

There are three basic terrain classification systems. The first of these systems is based on physical geography. Used primarily for large areas, it utilizes general descriptions such as "mountains" or "desert plains". Most of the terrain information in the world is expressed in terms of this classification.

The second system is based on geomorphology. More definitive than the physical geographic system, this system includes in the description the causative agent or the relation of the subject to its surroundings. Examples of this system are "alluvial fans" and "fault-block mountains".

The third system is based on physiographic associations. A multitude of factors, such as weathering agents, vegetation, soil types, and climate are considered in mutual relationship. This system is the most preferable for quantitative description of test parameters, but is extremely demanding in data, analysis, presentation, and application. It does have the advantage of permitting meaningful integration of similarly developed classification systems for other environmental factors.

3.1 DESERT TYPES

Deserts of the world possess certain basic terrain types. The predominance of any one type will change as the area progress to a more mature stage (Figure 1).

There are three main types of deserts: rocky deserts, gravelly deserts, and sandy deserts. There are also border areas, such as desert plateau (mesa and butte) and mountains or peaks and minor areas such as clay deserts (Figure 2). The three main types of deserts are as follows:

a. Stony Deserts - At the foot of mountains, the eroded rock surface may be steep enough that only large boulders or rock fragments are left on the surface. This hard rock surface, or "hammada", is the heart of the Stony Desert. It is bordered by mountains, bajadas and plains dissected by washes. Its surface consists of exposed bedrock, with scattered boulders and rubble, and scattered thin sheets of wind-deposited sand. In the transition zone between hammada and alluvium, an increasingly thick veneer of gravel is deposited.

b. Gravelly Deserts - Towards the lower levels of the desert floor, only the finer material is found. These gravels, pebbles and sand grains may be deposited in alluvium hundreds of feet thick. If there is no exterior drainage from the area, the surrounding highlands forming a basin, the infrequent flooding may result in ephemeral lakes. Suspended fines are left behind as the waters evaporate, and form playas. Changing water tables may

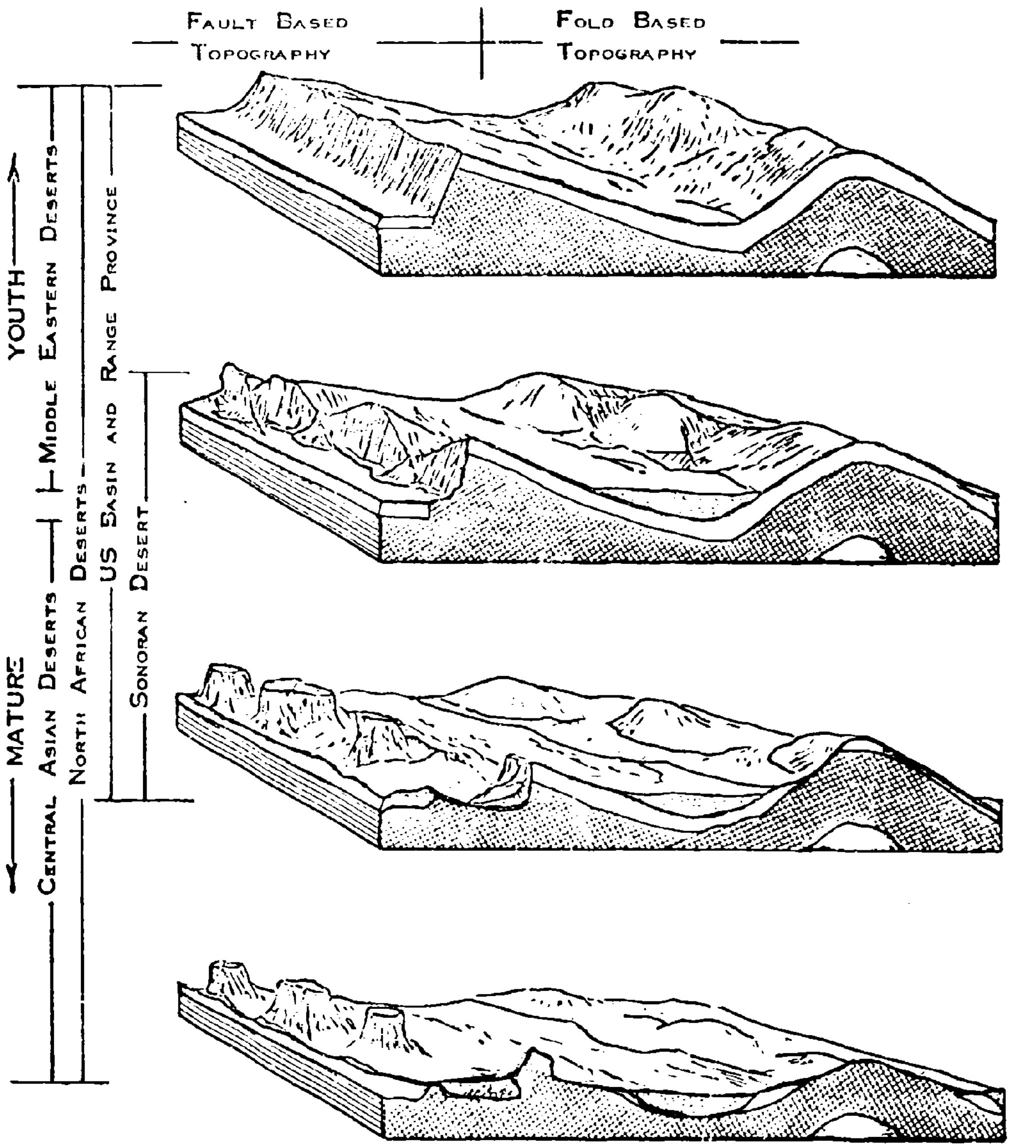


FIGURE 1 Stages in the Development of Desert Landscapes

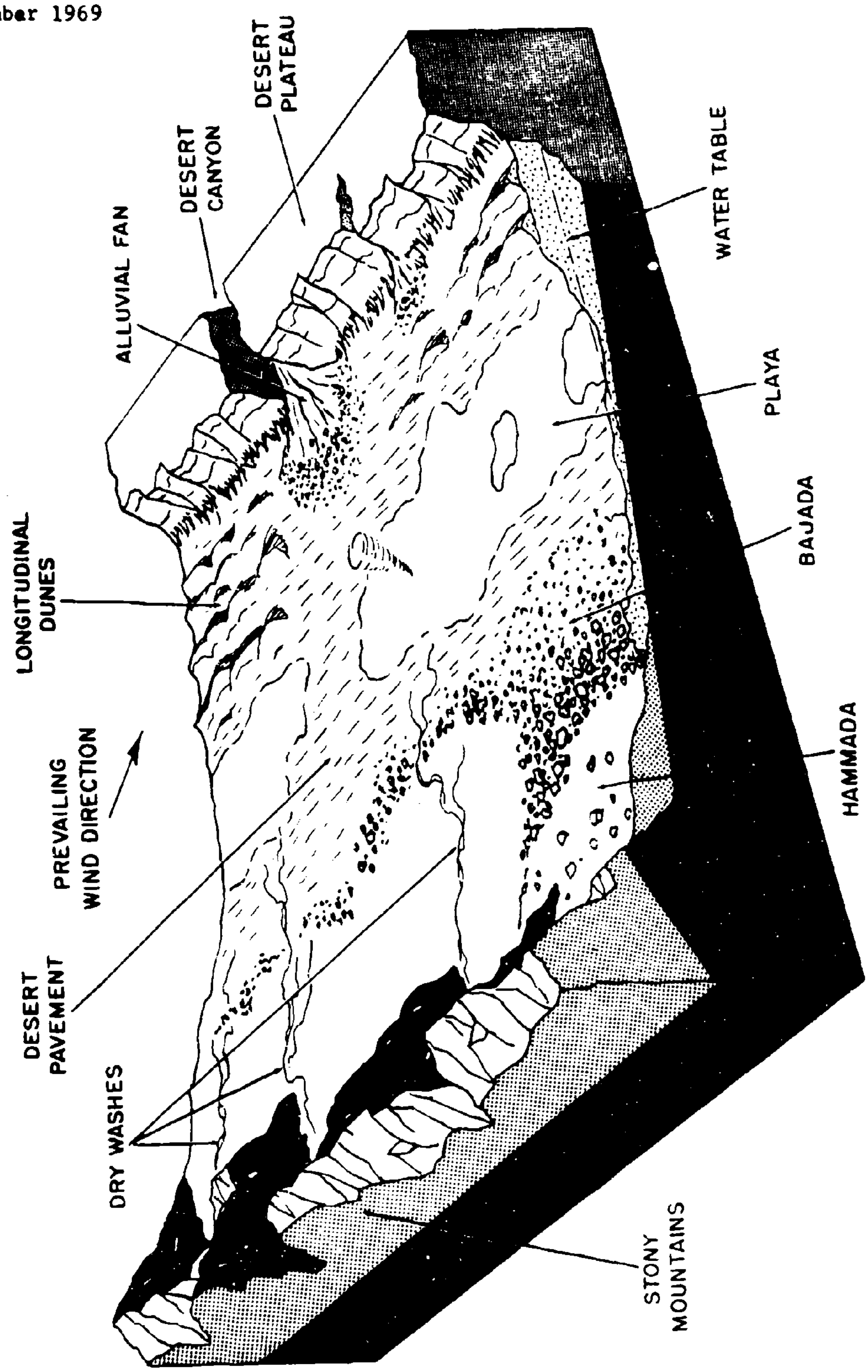


Figure 2 Desert Types and Border Areas

bring dissolved minerals to the surface, forming pans. This rock alluvium is the dominant feature of Gravelly Deserts, the most common desert type. It is made up of gravel stratum, mixed with sands and silts. The surfaces are usually poorly consolidated, bounded by bajadas or individual fans, and cut by washes. If strong prevailing winds are present, surface sand and dust may be blown away, leaving a tightly fitted mosaic of gravel behind. This mosaic is known by many names, but commonly called "desert pavement" in the United States.

c. Sandy Deserts - The wind-blown fines from the rocky and gravelly deserts are the material which form the Sandy Deserts. The material may be deposited in long, thick sheets, or centralized in dunes, which travel with the winds. Sandy deserts are usually bounded by gravelly deserts. On the downwind side they may abut on mountains or bajadas. Transition areas are typically covered by thin sheets of sand, overlaying resistant gravels.

3.2 DESERT COMPONENTS

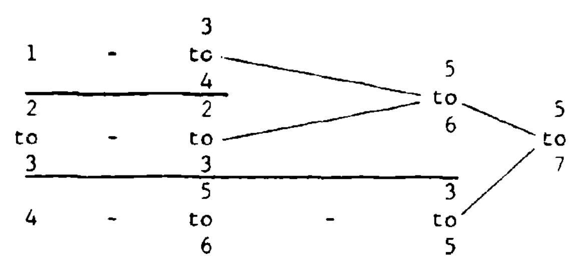
As previously discussed, similar components are found in all deserts in varying degrees, depending on the stage of development of the particular desert. An exhaustive listing of these components would cover many pages. Fortunately, these components can be summarized under certain broad headings, for the purpose of discussion. These summaries include mountains, badlands and hills, fans and washes, desert flats and plains, and sand dunes and fields. Each heading is discussed in more detail in the following paragraphs. The physiographic association classification used by the Corps of Engineer Waterways Experiment Station, Vicksburg, Mississippi, (WES) may be used to provide quantitative descriptions of desert components, (Figures 3 and 4).

The WES landscape classification is based on a four digit code. These four digits can be used to describe either component or gross landscape (Fig. 3). The first digit describes the characteristic plan-profile as shown in Figure 3. The second, third, and fourth digits describe the slope occurrence, characteristic slope and characteristic relief respectively (Table I).

3.2.1 Mountains

Included under mountains are the areas of the desert plateau, crossed by canyon like valleys of rivers and isolated sections of plateau in the form of mesas and buttes in actual rock peaks, as in the TIBESTI and AHUGGER Ranges of the central Sahara, the chaotic peaks of Sinai, and the mountains of Western Arabia and those of BALUCHISTAN.

The WES classifications include:



CHARACTERISTIC PLAN-PROFILE

The characteristic plan-profile is the most commonly found plan-profile within a region. It may be either gross or restrictive. A gross plan-profile is one that can be subdivided into two restrictive component plan-profiles each exhibiting relief of a lower order than the gross plan-profile. Random sampling with circles 35 miles in diameter is used in determining the gross profile. Random sampling with circles 1 mile in diameter is used to determine the restrictive plan-profile. Local relief of less than 10 feet is not considered.

LEGEND

Highs* Occupy:	Highs are → / Schematic Plan / Schematic Profile		Non-linear and Random	Linear and Random	Non-linear and Parallel	Linear and Parallel
>60% of area	Flat-topped		1	1 L **	1// ***	1L //
40-60% of area	Flat-topped		2	2 L	2 //	2L //
<40% of area	Flat-topped		3	3L	3 //	3L //
>60% of area	Crested or Peaked		4	4L	4 //	4L //
40-60% of area	Crested or Peaked		5	5L	5 //	5L //
<40% of area	Crested or Peaked		6	6L	6 //	6L //
No pronounced highs or lows			7			

REPRESENTATIVE PLAN-PROFILES

Each of the following block diagrams illustrates a landscape representative of a specific plan-profile type. It should be emphasized that, within the defined limits of each type, a wide variety of landscape configurations are possible.

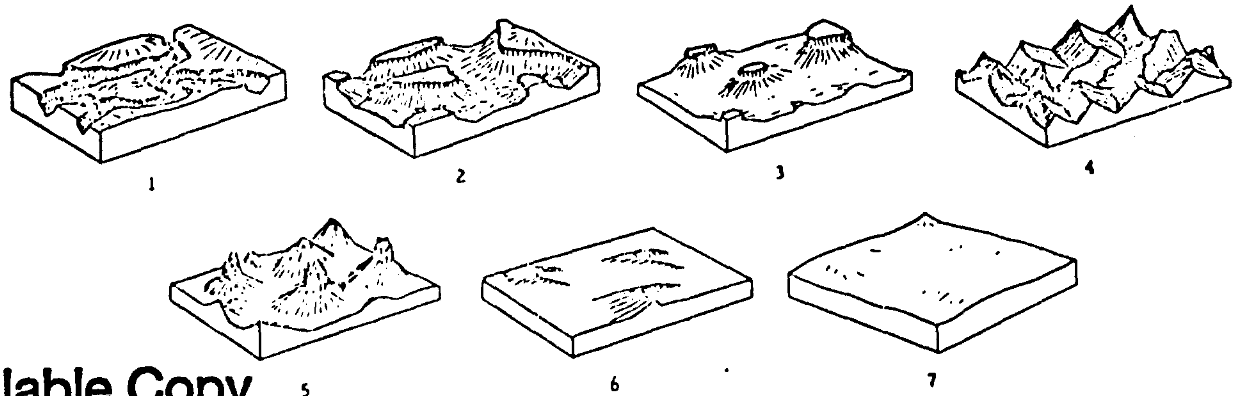
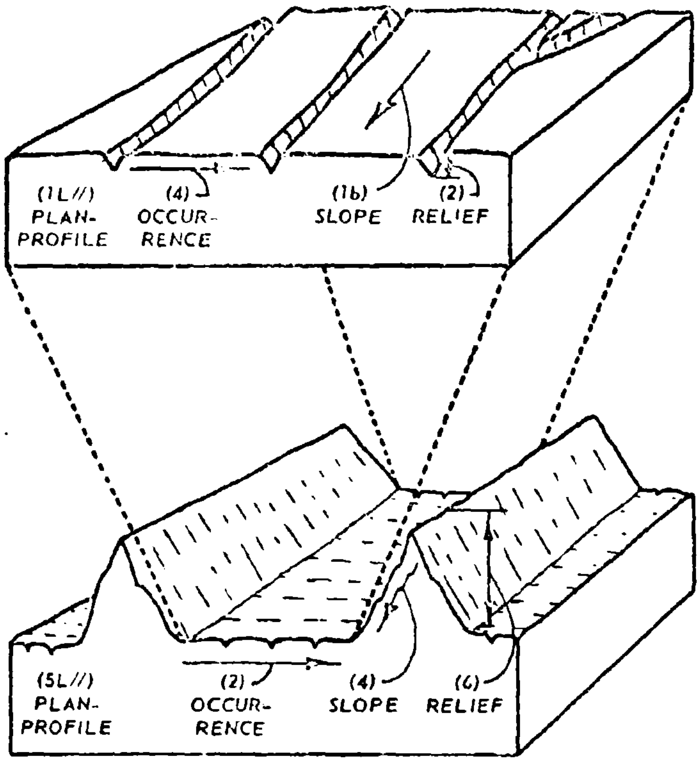


FIGURE 3

COMPONENT LANDSCAPE

A PLAIN WITH A 1 TO 3.5% SLOPE DISSECTED BY ROUGHLY PARALLEL WASHES FROM 10 TO 50 FT DEEP, SPACED FROM 1000 TO 5000 FT APART



GROSS LANDSCAPE

A PARALLEL RIDGE AREA WITH THE RIDGES FROM 2 TO 10 MILES APART, THEIR HEIGHT RANGING BETWEEN 400 AND 1000 FT, AND THEIR CHARACTERISTIC SLOPE BETWEEN 25 AND 50%

FIGURE 4

TABLE I. Terrain Factor Coding

Factor Code	Slope Occurence (per 10 miles)						Characteristic Slope (deg)							Characteristic Relief (ft) Type 1			Type 2			
	< 1	1 to 5	5 to 20	20 to 100	100 to 200	> 200	0 to 1/2	1/2 to 2	2 to 6	6 to 14	14 to 26-1/2	26-1/2 to 45	> 45	0 to 10	10 to 50	> 50	0 to 100	100 to 400	400 to 1000	> 1000
1	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-
1a	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-
1b	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
2	-	X	-	-	-	-	-	-	X	-	-	-	-	-	X	-	-	-	-	-
3	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	X	-	-	-	-
4	-	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	X	-	-	-
5	-	-	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	X	-	-
6	-	-	-	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	X	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X

3.2.2 Badlands and Hills

Badlands and hills include the areas of extremely rough terrain, limited only be relative relief from the mountain classification. Slopes are steep, even vertical. Ridges are flat, rounded, or knife-edged, depending on the type of material and the stage of development. Surface materials vary from silt-sand mixtures through gravels.

The WES classifications include:

1	2	5 to 6	5
4	3	4	4 to 5
	4	3 to 5	3 to 5
	5	3 to 4	4 to 5
6	2	4	5 to 6

3.2.3 Fans and Washes

The term "fans and washes" includes coalesced alluvial fans, known as "bajadas". Fans are made up of water transported sediments, deposited at the mouths of canyons and valleys in a radiating surface similar to a segment of a cone. Stream channels, or washes, are cut deep into the heads of fans, while they divide into several braided channels across the foot of the fans.

The fan and wash complexes include the following WES classifications;

1	4	-	1b to 2	-	2
1	3	-	2	-	2
7	1	-	1b	-	1
7	3	-	1b to 2	-	2

3.2.4 Desert Flats

Desert Flats, also known as "valley flats" and "alluvial plains" cover the bulk of desert surfaces not covered under other headings. They include the "desert pavement"; the valley alluvium; gravel covered terraces; and the various playas.

The following WES classifications fall within the "desert flats" category:

1	-	2 to 3	-	1a to 2	-	2 to 3
7	-	1 to 2	-	1a to 2	-	1 to 2

3.2.5 Sand Dunes and Fields

The areas covered by "sand dunes and fields" is self-explanatory. The significant factor is the sand surface; land form geometry is similar in many instances to other terrain categories. WES classifications which cover sand dunes and fields includes:

4	3 to 4	-	3	-	4 to 5
	5	-	3	-	4
5	3 to 4	-	3	-	4 to 5
	4	-	2	-	3
6	1 to 3	-	3	-	5
	3 to 4	-	2	-	2

4. DISTRIBUTION

The distribution of these types over the world's deserts is indicated in Table II. This table is based on WES studies of the world's deserts for analogy with the desert at Yuma Proving Ground. Entries for each heading are based on the classification groupings shown above. Data is based on WES reports.

TABLE II. Distribution of Desert Components in World's Deserts

	NE Africa	NW Africa	Mid-East	S Central Asia	World*
Total Area (1000 sq mi)	1916	2013	1390	784	6247
% of Total Area:					
Mountains	13.4	17.8	18.2	28.2	18.0
Hills	7.4	8.2	2.2	2.3	5.7
Fans	16.6	6.2	20.8	25.2	16.9
Flats	41.6	37.4	31.1	20.2	33.9
Playas	3.9	8.8	6.4	14.1	7.3
Dunes	17.0	19.1	19.0	10.2	16.8
Misc**	0.2	2.4	2.6	-	1.4

*Total considered area of world deserts includes Mexican deserts.
**Includes hammadas, river terraces, volcanic cones and dikes, etc.

5. TESTING REQUIREMENTS

Material will be influenced by the terrain environment during three testing phases. These phases are transportation, storage, and performance. During each of these phases, different parameters of the terrain environment affect the test item.

In the following sections we will combine these parameters and the

factor data discussed above. These combinations will be used for developing testing requirements for each of the three phases.

5.1 TRANSPORTATION

Equipment and supplies sense two aspects of the geophysical environment during the transportation testing. The first aspect is the shock and vibration transmitted by the carrier. The second is contamination from sand and dust.

Shock can be realistically represented by using carriers similar to those employed during field operations, and by testing on terrain representative of the world's deserts. Although each terrain component can be identified in a desert complex, its relative importance will vary according to the type of desert. Since these factors act in succession to compound the stress history of a test item, they should be considered in their normal associations. Thus items should be exposed to desert types as described above, rather than a random series of factors.

Table II shows a percentage distribution of components among the desert types. Included in the table is the world's desert distribution from Table III.

The mileage tables in MTP 10-4-001, are based on this distribution. Ten miles of operation on a dust course are included to determine the effect of heavy dust concentration on the test items and their containers.

TABLE III. Distribution of Desert Components as a Percent of Desert Types.

	Components				
Types	Mountains	Badlands	Fan/Wash	Plains/Fields	Dunes/Fields
Stony	20	30	20	30	-
Gravelly	-	20	20	50	10
Sandy	10	10	-	30	50
World	18.0	7.1	16.9	41.2	16.8

5.2 STORAGE

Due to the danger from flash floods, supply points are normally located on elevated terrain features, which effectively eliminates washes, gorges, draws and playas from the list of probable terrain components forming storage environments. Likewise, for security from detection, and to reduce vulnerability, exposed elevations (upper slopes, hill tops, ridge crests, etc) are avoided. Sandy areas, particularly dunes, present problems because of their lack of stability, and the hostile wind/sand environment existing in the zone from 0 to 1 meter above the surface. Consequently, these areas are to be

avoided for prolonged storage of supplies.

Considering the above, the lower slopes of hills and mountains, and the interfluve areas of fans and flats can be considered the most probable location of storage dumps. For the purpose of testing, therefore, storage types should be located on desert pavement, or gravelly or rock strewn desert. From the standpoint of camouflage (see also MTP 10-4-001), such areas that have vegetation will be sought. However, cacti and other succulents are limited generally to the North American deserts. To summarize, a storage area representing probable storage areas in the world's deserts should have the following characteristics:

a. Surface composed of gravel or rocks.
b. Fines present in limited amounts.
c. Bearing strength medium to firm.
d. Non-succulent xerophyte vegetation in limited quantities.

5.3 PERFORMANCE

Microrelief, localized soil types, particle shape and gradation generally all have a more profound effect on equipment performance than the gross conditions considered above. The parameters which should be measured are stated in MTP 10-4-001. The terrain components in which these factors can be found are shown in Table IV.

The test planner must decide which factors are most critical to the item being tested, and select his performance test sites accordingly. Many items (particularly those which are "consumed" rather than "operated") will be independent of the terrain factors above, as far as selection of test sites. In the latter case, consumption tests would be based on representing each major desert type (Table III).

TABLE IV Micro-Geophysical Factors Most Commonly Found in Various Desert Terrain Components (a)

Micro-Geophysical Factors				Mountains	Badlands and Hills	Fans and Washes	Desert Flats	Sand Fields and Dunes
Slope			Flat to 3.5%	-	-	X	X	X
			Gentle to 10%	-	-	X	X	X
			Moderate to 25%	-	X	-	-	X
			Declivitous to 50%	X	X	(b)	-	X
			Steep to 100%	X	X	(b)	-	-
			Precipitous -> 100%	X	(b)	(b)	-	-
Surface Cover	Coarse Grained Soils	Rocky	Boulders (> 50%)	X	X	-	-	-
			Cobbles (3-12 in.)	X	X	X	-	-
			Gravels (> 70%)	X	X	X	X	-
		Sandy	Gravel-Sand	-	X	X	X	-
			Sands (> 70%)	-	-	-	X	X
	Silts and Clays			-	-	-	X	-
Soil Consistency	Homogonous	Noncohesive	Loose	-	-	X	-	X
			Dense	-	X	X	X	X
		Cohesive	Soft	-	-	-	-	-
			Firm	X	X	X	X	-
			Hard	X	X	X	X	-
	Layers	Cohesive	Hard, thin crust	-	-	-	X	-
			Hard crust	-	-	X	X	-
		Noncohesive		-	-	X	X	X

(a) Other factors may be found in almost any component, but not in enough area to constitute a significant percentage. This is particularly true in areas where there has been human activity (mining, construction, etc).

(b) These conditions will be found principally along stream banks.

GLOSSARY

1. <u>Alluvial Fan</u>: A body of alluvium, shaped like a segment or sector of a low cone, formed where a steep mountain canyon emerges into an open valley or onto a plain. The surface of an alluvial fan is normally marked by steam channels and former channels that radiate from the opening of the cone, at the mouth of the mountain canyon, in a pattern somewhat like that of the ribs of an open Japanese fan. The profile of a large alluvial fan is normally concave, the slope decreasing progressively away from the apex.

2. <u>Alluvium</u>: A general term for all soil, sand, gravel, or similar detrital material deposited by running water. Occurs on flood plains of streams or on alluvial fans and cones at places where streams issuing from mountains lose velocity and deposit their contained sediment on a valley floor.

3. <u>Bajada</u>: A long outwash detrital slope at the base of a mountain range, resulting from the coalescence of alluvial fans. (alluvial slopes, piedmont slopes).

4. <u>Butte</u>: An isolated, flat-topped hill or mountain with steep sides. Buttes are most common in arid regions.

5. <u>Fine-Grained Soil</u>: A soil of which more than 50% of the grains, by weight, will pass a No. 200 sieve (smaller than 0.074mm in diameter).

6. <u>Ephemeral Lakes</u>: Playas which are subject to intermittent flooding, the water usually evaporating after a few days.

7. <u>Fault</u>: A movement or displacement of the rock on one side of a fracture or break in the earth's crust past the rock on the other side.

8. <u>Hammada</u>: A desert surface that is either bedrock or else bedrock covered only by a very thin veneer of sand or pebbles. The term was originally applied in the Sahara (where referred to a desert plateau of stones) but is now used for similar desert surfaces in other parts of the world.

9. <u>Mesa</u>: An isolated residual prominence with distinctly flat top and very steep or precipitous slopes left as erosional remnants of a plateau area.

10. Playas: The flat or nearly flat low part of an enclosed basin--essentially dry lakes which have expanded and contracted several times. Frequently used interchangeably with PAN, a feature with similar appearance but different structure. Playas include dry, moist (saline) crystal body, compound and artificial types. (Also called Salares).

11. <u>Stratum</u>: A single bed of sedimentary rock generally consisting of one kind of matter, representing a continuous deposition.

12. <u>Washes</u>: A dry drainage channel characterized by a relatively flat, gravel and sand bed (over 5 meters in average width) with nearly vertical walls. Called WADI in Africa.

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17. MTP 10-4-001, Desert Environmental Test of General Supplies and Equipment.
18. MIL STD 1165, Glossary of Environmental Terms (Terrestrial), dated 25 March 1968.

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13. ABSTRACT

This Background Document provides general testing information germane to the description of and the influences of desert terrain. This information supplements and is applied, in common, to test procedures which deal with the evaluation of specific commodity materiel items under desert environment conditions.

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